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# What Good Is Learning If You Don't Remember It?

William R. Klemm<sup>†</sup> *Texas A&M University, College Station, TX* 

#### **Abstract**

Teachers should emphasize the educational importance of understanding, but not at the expense of overlooking the importance of memorization skills. Currently, mainstream educational theory embraces such attributes as insight, creativity, inquiry learning, and self expression. But such emphases lead to a bias and under-appreciation of the role of memory in learning. Students cannot apply what they understand if they don't remember it. Moreover, a good memory expands the repertoire of cognitive capabilities upon which new understandings can be developed and expedited. Effective thinking does not occur in a vacuum. I advocate adding another "R" to the "three Rs": Reading, wRiting, aRithmetic, and *Remembering*. This paper attempts to show teachers how they can help students become better learners — and better thinkers — by improving their memorization skills

**Keywords:** Learning; Memory; Memorization; Strategies; Attention; Association; Association; Rehearsal; Recall

I have a faculty colleague who chastised me for writing a book for students on how to improve memory (Klemm, 2004). This colleague thinks that education should be all about understanding and using knowledge to solve problems. We need, he says, to teach students how to think. This colleague is like so many teachers these days who emphasize insight, creativity, inquiry learning, communication skills, and the like. In science education, inquiry learning is all the rage (Layman, Ochoa, & Heikkinen, 1996; Martin, Sexton, & Franklin, 2004; *Inquiry*, 1999). In the process of educational reform, the reformers discount the importance of memory.

I agree that the ultimate goal should be to teach people how to think, solve problems — and to create. Central to these capabilities, however, is the ability to remember things. The more one knows (remembers), the more intellectual competencies one has to draw upon for thinking, problem solving, and even creativity. Society does not need a workforce of trained seals, but it does need people with knowledge and skills. Knowledge and skills are acquired through memory.

Even our ability to think depends on memory. People think with their working memory, which is defined as small amounts of information accessible over short times that people can use in learning and thinking (Baddeley, 2000). I like to think of this memory meta-

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<sup>†</sup> Corresponding author's email: bill@thankyoubrain.com

phorically as "scratch pad" memory because it is all too easily erased, scribbled over, lost, or thrown away. The thinking process is a successive operation in which successive "chunks" of scratch-pad memory are moved into the thinking process. The information on that scratch pad must either come from new experience or permanent memory store and in either case the thinker must be able to hold that information in working memory long enough to complete the thinking process. Thus, it should not be all that surprising that there is tight correlation between IQ and working memory (Wickelgren, 2001) and with problem-solving ability (Carpenter, Just, & Shell, 1990).

This paper's title is an explicit statement of my thesis. Understanding information is certainly desirable, but what good is it if you don't remember? How many Ph.Ds., for example, learned a second language they no longer can use? I will concede that there was some good, but only in the sense that this initial learning had a priming effect on memory (Bowers & Marsolek, 2003) that would make it easier for me to re-learn these languages. Parenthetically, the main burden of learning a language is on memory of rules of syntax. grammar, and vocabulary. How much understanding is needed depends on the subject of writing or talking. Learning differential equations requires more understanding than gross anatomy. But memory is even important in abstract subjects that seem to require more understanding. I remember as a college freshmen taking engineering math and going into the final exam with an F average because I was trying, and failing, to understand everything. I decided to study for the final exam by memorizing all the formulas and all the situations to which they applied. I made a 100 on the final and passed the course. Along these same lines, a middle-school math teacher once told me that her Special Education students could do the same level of math problems as regular students if only they could remember the steps.

Think back to your school days. How many teachers explicitly taught you how to remember effectively and efficiently? Your teachers may have used a couple of acrostics, and limericks. They probably warned you not to cram. That may have been the extent of your formal education in how to learn. The emphasis in school is always on *what* to learn and what it means. Who teaches *how* to learn?

Do today's students know how to memorize? I don't think so. Most students, and many of their teachers, memorize by rote. Rote memorization is not only inefficient, but it encourages learners not to think - just memorize. There are ways to make memorizing much more effective, with less effort, and also more fun. Durable memory assumes even greater importance than ever in this era of high-stakes testing. Students may acquire a given skill or knowledge set on the day you teach it, but will they remember it for the annual state-mandated tests? The trouble is, most teachers don't know about these more fun ways of memorizing. Also, there are many generally under-appreciated variables that affect memory, whether done by rote or by assorted association techniques. The point of this paper is to show teachers how they can help students remember better what they have already learned and understand.

## **Elements of Remembering**

Contributing to the memorization processes are the following key elements: (1) Registration & Attention, (2) Association, (3) Rehearsal, (4) Consolidation, (5) Cueing & Recall. To remember, the information has to register, and to register you have to pay attention (Figure 1). To register information, attention must be paid to the sound or light stimuli that bring the information into the brain. Not registered, not remembered. The notorious decline of memory with age is commonly an attention-deficit problem (Grady et al., 1995).

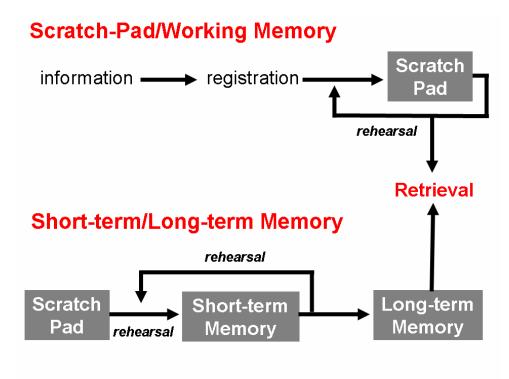


Figure 1. The process of remembering.

No school teacher needs to be told that paying attention is important for learning. It's the kids who don't appreciate how important attentiveness is. Attentiveness is central to the process of encoding, which entails acquiring information and placing it into working memory storage (Brown & Craik, 2000). Paying attention also augments the encoding by enabling rehearsal at the same time and the information is rehearsed, the more likely it is that it will be put into longer-term memory storage. These are the reasons why good teachers strive to make learning interesting and salient enough to engage student attention. In my own experience, students with the best grades are generally more visibly attentive during class periods, showing clear signs that they are consciously aware of what is being said and seen and that they are "working with" (and rehearsing) the information by their comments and questions.

While it is true that memories can be formed when the brain is on "automatic pilot," this kind of learning is mostly implicit, and the process is more error prone and not nearly as

effective as when conscious effort is devoted to attending to memory tasks (Cowan, 1997).

Information first goes on a virtual scratch pad and even at this level some rehearsal is necessary to keep it accessible. As an example, recall what you do when you look up a phone number. If you don't rehearse it once or twice, the number will be lost before you can get it dialed.

Effective memorization occurs when you can make an association between the new and what you already know. As Cowan (1988) puts it, "new information must make contact with the long-term knowledge store in order for it to be categorically coded." I would add that it seems self evident that not only the category is coded but also the content itself. Associations, whether constructed implicitly or explicitly, need to be rehearsed, with a minimum of distractions and interference (McGaugh, 2000). This rehearsal leads to consolidation into longer-term memory. Recall is expedited if there are many association cues used during the initial learning and during the recall attempt.

In the scratch pad state, memory is only accessible so long as no new information over-writes the "scratch pad." Another problem with scratch-pad memory is its limited capacity. Rehearsal during this working memory stage may make memory less volatile, and may even convert short-term memory into long-term memory. This process is known as consolidation and has been studied for about a hundred years (McGaugh, 2000).

Teachers are most interested in having students remember their lessons long after the time they are first presented. Yet most students study from test to test. Occasional rehearsal of old-test material is needed for longer-term memory. That is why final exams are so difficult for students. That is why a summer break erases much of the educational progress that was made during the year. What is really important to educational effectiveness is the consolidation process by which short-term memory is converted to long-term memory.

My own model for effective memorization (Figure 2) is based on well-accepted principles of the processes for converting temporary memory into permanent form. Initially, new information resides on the brain's "scratch pad," and it undergoes two important analyses. The information needs to be compared with what is already known. This comparison ideally includes making associations with what is already known. These associations can then serve as cues that become imbedded with the new information and can be used later to facilitate recall. New information also should be evaluated for relevance and importance. Memory is "event dependent." We remember best things that make a big impact. If there is a large emotional component, the memory may be facilitated or impaired (Cahill, 2003). If a learning experience does not make a big impact on its own, students would do themselves a service by contriving ways to enhance the salience of the information.

Salience information also becomes embedded with the new information, often in implicit ways that can facilitate later recall. If associations and salience are optimized as part of

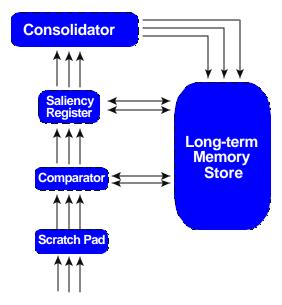


Figure 2. The memory consolidation process.

the working memory stage, consolidation into long-term memory has a chance to occur.

Consolidation is vulnerable to interference from new stimuli and learning effort. Memory researchers generally embrace the "interference theory of forgetting," which posits that remembered events or items and their associations must compete with other such associations that occur shortly before or after. Such interference can even occur with the recall of well-established memories. Interference effects diminish as the time gap increases between target learning and interference (Bower, 2000; Roediger & McDermott, 2000).

#### Recall

Many memories endure even though they cannot always be re-called on demand (Tulving, 1974). Classic examples in education include the common lament of students who remember certain exam answers, *after* they turn in their test papers. The explanation is that memory retrieval depends on the cues that were associated during learning. Failure to recall the right cues leaves the memory buried. Retrieval is actively impaired by stress, commonly known as "test anxiety."

The "tip-of-the tongue" phenomenon is usually a situation where anxiety blocks retrieval of something that is in memory storage. The cure is to relax and avoid self-pressure. Students need to think of all the cues that must be associated with what they want to recall. Often, an answer comes to mind that students know is wrong. Wrong answers are more than a distraction — they actively interfere with recall of the correct answer and must be forced out of mind. Recall is facilitated by having confidence in one's memory ability and by the belief that the memory will be retrieved once self-pressure is removed. In an exam situation when this problem occurs, test takers should move on to another question and expect the recall the "lost" information to pop-up later.

#### **Emotions**

The more important information is, the better chance a learner has to remember it. This leads us to the issue of attitude. Too often students have a negative attitude about academic subject matter, and this attitude is self-defeating. It not only makes study tedious but it impairs the ability to remember it. If you want to remember something badly enough, you will. Students do themselves a favor by contriving ways to make all their study material important and interesting. Students who indulge a negative attitude about the teacher or the subject matter mostly punish themselves.

Retrieval is mood dependent (Mineka & Nugent, 1995). In one study, college students were instructed to write a daily diary for a week, and then they were hypnotized and put in either a happy or a sad mood. Happy students remembered more of the happy events in their diary, while sad students remembered more of the unpleasant incidents. Depression, a common emotion among youngsters, generally impairs memory for everything except memories that add to the depression (Kizilbash, Vanderploeg, & Curtiss, 2002).

Negative emotions cause stress. Personal problems, puberty, social conflicts, grade pressures, test anxiety and the like are common causes of academic underachievement. One of the main reasons is impaired memory capability.

Test anxiety deserves special mention. Not only does such anxiety, if it occurs all the time, interfere with memory (Newcomer et al., 1994), but it also has the potential to kill memory-forming neurons (Sapolsky, 1992). The corticosteroid hormones released during stress can actually kill neurons, and the most vulnerable ones appear to be in the hippocampus, the brain structure that is crucial to consolidating short-term memories into long-term form. Chronic stress induces a progressive loss of memory ability that is especially pronounced in older humans (Lupien et al., 1998).

#### Getting Enough Sleep

A day's learning experiences are still being consolidated during that night's sleep. In fact, sleep is necessary for full consolidation (Plihal & Born, 1997; Stickgold, Whidbee, Schirmer, Patel, & Hobson, 2000; Van Dongen, Maislin, Mullington, & Dinges, 2003). The typical adolescent or college student does not get enough sleep for optimal learning. People this age often need nine or more hours of sleep a night. Numerous research studies have shown that both ordinary and dream sleep contribute to the consolidation process for experiences of the preceding day. Memory rehearsal apparently goes on subconsciously while we sleep.

## **Specific Memorization Strategies**

The strategies I will mention below work at least to some degree with all kinds of memory, which currently are often characterized as procedural (motor or cognitive skills, simple conditioning), priming, working, semantic (general facts), and episodic (personal events) (Tulving, 1995). These strategies have not been systematically compared for effi-

cacy for each category of memory, but it seems reasonable to believe that they are generally helpful.

#### Attention

Experienced teachers don't have to be told how important paying attention is. But most students need to be reminded. Even if a lecture or a book is boring, failure to pay attention constitutes self-punishment. Under these conditions learning may never occur or be marginal and will certainly take longer than would otherwise be necessary. Anything not learned in class may have to be learned later. Students need to be reminded that attention in class makes remembering much more efficient.

Part of paying attention is to focus. And focus does not occur when students are multi-tasking. We their elders tend to be impressed by the ability of today's youth to multi-task: they can simultaneously talk on the cell phone, browse the internet, IM message, play videogames, listen to their iPod, watch TV, and do their homework. Attentiveness degrades severely with high working-memory load. It is hard to do two complicated things at once. But actually, multi-tasking is most likely to interfere with focused attention and, in turn, degrade memory formation and recall (de Fockert, Rees, Frith, & Lavie, 2001). Studies now confirm that multi-tasking interferes with homework (Foerde, Knowlton, & Poldrack, 2006). Nobody can do anything optimally when multi-tasking. Case in point: many states have laws against talking on a cell phone while driving. And driving a car is a lot easier than memorizing something like differential equations.

## Organization

The first organizational step is to identify in new information the parts you already know and the parts that can be figured out. Why memorize what you can figure out? When it comes to memory, less can be more.

Next, information is remembered best when it is organized by category. Abundant anecdotal reports, especially from "memory wizards" indicate that it is easier to remember items or concepts that are related and associated accordingly, because any one item can serve as a cue that helps to dredge up recall of the others. The value of categorization has been documented in studies of neural networks, which "memorize" new information by categorizing it. Learning progresses with progressive refinement of distinctions of input patterns. The matching process compares whole patterns, not just separate features (Carpenter & Grossberg, 1988).

Actually what makes the memorization of items more effective when they are categorized is placing items together that have natural associations, such as table/chair/dinnerware/food. Formal studies have shown that a recall list of words that have natural associations is learned better than lists of words that are not normally associated. This ability to benefit from clustering of like items is age-dependent; young children do not show the same benefit as older children (reviewed by Cole & Means, 1981).

#### Association

We learn best by associating the new with what we already know. Rote memory is the most inefficient kind of memory because no associations are made.

Associations are most effective when they are visual images. Memory theorists have a long tradition of analysis of procedural memory (for skills), episodic memory (of autobiographical events), and of semantic memory (for words). Only since the 1960s has much attention been given to visual-image memory, despite the thousands of years of anecdotal evidence that visual images profoundly facilitate memorization (Bower, 2000; Tversky, 2000). The little formal research that has been performed does confirm that pictures are remembered better than words.

There is a good neurophysiological reason why images are so effective. The brain devotes vastly more neuronal resources to vision than to hearing. Another indicator of vision's superior capability is the fact that there are about one million nerve fibers in the nerve coming from one eye but only about 30,000 fibers coming from one ear. And the amount of neurons devoted to understanding language is one small zone not much larger than a quarter, while the whole back of the brain is devoted to vision and much of the right hemisphere is devoted to geometric and spatial relationships.

Teachers like to talk. But students would probably learn more if teachers spent more time drawing. Likewise, students should try to put more diagrams and doodles in their notes than pure text. People who put on "memory shows," such as the six-time World Memory Champion whose astonishing feats of memory are accomplished by making visual images of whatever they are trying to remember (O'Brien, 2000). The images work best when they are bizarre or ridiculous. Images should be based on vivid nouns, because nouns are concrete and easy to image. One effective strategy is to link images together as a story.

Cues are important to good associations. The more cues used in forming an association, the more readily the memory will be consolidated and the more access routes one will have when trying to recall. The reason is that information is distributed throughout widely scattered networks of brain circuitry, much like a fish net. Cues are like the knots in a fish net, any one of which can be used to gain access to the entire net.

The situation in which learning occurs also provides cues that get imbedded with memory of the learning. Learning that occurs under the influence of alcohol, for example, is recalled best when under the influence of alcohol (Lowe, 1983). In a study where scuba divers were given a list of words to remember, either under water or on the beach, they recalled best when tested in the same place where they first learned (Godden and Baddeley, 1975). An important memory cue is spatial location where the learning occurs (Leutgeb et al., 2005). Learning acquired in a classroom is recalled best when testing is conducted in that same classroom. Students would probably perform better on statemandated testing if tests were administered in the same rooms in which the material was taught.

#### Chunking

Because scratch pad memory is finite and limited, trying to memorize in large chunks does not work well. Extra information cannot be held on the scratch pad. A limited capacity for working memory was firmly established in classic experiments by Miller (1956). These experiments led to the commonly accepted notion that working memory capacity is limited to a "magical number of seven, plus or minus two" items or chunks. (This is why local phone numbers have seven integers.) Strings of numbers typically have some built in dependencies and we now know that the capacity for truly independent items is typically only four or less items (Cowan, 2005). If information chunks exceed working memory capacity, the brain must either drop the extra items from further processing or it must over-write what was already there. Working memory operates on what is on the scratch pad. Consolidation of working memory cannot occur if what is there keeps changing too fast.

All chunks of learning material benefit from being linked as small steps toward a final goal. Each step is learned in the context of the ultimate purpose, and memorization builds through rehearsal as each step is linked to the next.

#### Rehearsal

The key role of rehearsal is most obvious with rote memory, because rote memory only works when the information is repeated, often numerous times. The same effect is seen with motor learning, as practice is essential to perfect such learned actions as touch typing, piano playing, or kicking field goals. This repetition is needed to promote consolidation of working memory into longer-term form. Consolidation is time-dependent (McGaugh, 2000; Shadmelu & Brashers-Krug, 1997). It takes many minutes of uninterrupted rehearsal for many things to get consolidated. Interposing new information or stimuli while other information is in the process of consolidation may well interfere with consolidation. Think about the typical classroom environment: about 5-10 minutes before class is scheduled to end, students start getting agitated, looking around and shuffling papers. Then the bell goes off, and they rush out to visit in the hall or dash off to the next class. What do you think happens to the learning that was on their brains' scratch pad?

Rehearsal strategy is something that children learn as they mature, apparently by trial and error, because many children get no specific memory training. Younger children, for example, do not perform as well as older ones on serial recall tasks and the reason is that they fail to rehearse cumulatively the study items as they are sequentially presented. Likewise, younger children do less well in "keeping track" tasks in which items in a heterogeneous group are presented and they are asked to keep track of "What was the last *food*, or *animal*, or *vehicle*?" Such inabilities are conspicuous in poor learners, regardless of age. Explicit training in cumulative rehearsal improves learning by poor learners (Cole & Means, 1981).

The goal of teachers and students should be to reduce the amount of rehearsal needed to achieve consolidation. Even with good memory practices, rehearsal needs to go on every

day, even if only for a few minutes. Such short-rehearsals close to the time of original learning greatly facilitate the formation of long-term memories in the most efficient way. If you learn something and don't rehearse if for a day or so, chances are you will have forgotten it and have to start over from scratch. There will be a residual "priming" effect, but it isn't worth much.

The extreme of bad rehearsal practice is to cram for tests a day or so before a test. Such an approach creates only short-term memory, and if sleep deprivation is involved, even the short-term memory will be impaired. Most students will invariably study by cramming if the testing is structured to allow that. No teacher should be satisfied to have students learn only for the next test, yet too often testing is not based on a philosophy that learning is to be permanent.

Another point that relates to testing is the use of multiple-choice tests. These test recognition memory, the lowest form of usable memory. Multiple-choice tests have high odds for guessing the right answer. Also, an answer can be recognized as correct even though the student may not be able to generate the answer. I have tested this matter several times with my students and observed that class test scores always go down on the order of 20-40% when I switch the same questions from multiple-choice to short-answer form.

## A Teaching Game-plan That Works

To put the forgoing ideas into a practical framework for teaching, I recommend a '10-minute rule.' The rule goes like this: teach/learn something for 10 minutes. Then for the next 10 minutes rehearse and apply that information in some way. It might be in the form of discussing the information or re-organizing notes or developing image associations to help memory. Then take a few minutes of break where the material in rehearsed in the mind without any interruptions or new information. Then a new set of instructional material can be considered in the 10-min-rule format. Successive 10-min segments can use the chunking model just mentioned in which core knowledge is successively linked toward mastery of a larger set of competencies.

This kind of teaching strategy optimizes attentiveness, association making, chunking, and rehearsal, while at the same time minimizes interference effects. Such teaching should promote a more complete, contextualized learning environment that can not only raise test scores but also be more effective in producing memories that lead to transportable skill acquisition and problem-solving capability.

#### Conclusions

Many students underachieve in school because they have never been formally instructed in how to memorize. They typically memorize by rote, which is the least efficient and least effective way to memorize. They also may have not been told about the many variables that adversely affect the ability to memorize, such as the way they try to memorize, their attitude and emotional state, stress, and lack of sleep. Teachers will be more likely

to get better results if they take a little time away from telling students what to learn to tell them how to learn.

The many kinds of information presented in school settings often benefit from specific tactics for optimal memorization. For that reason, I have started a free memory advice column on the Web. In addition, I have also started a Weblog where I summarize memory research that can be applied to improve everyday memory ability. Both the column and the Weblog can be found at http://thankyoubrain.com.

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